

Probing lateral E fields with x-rays

Andrei Nomerotski (BNL)

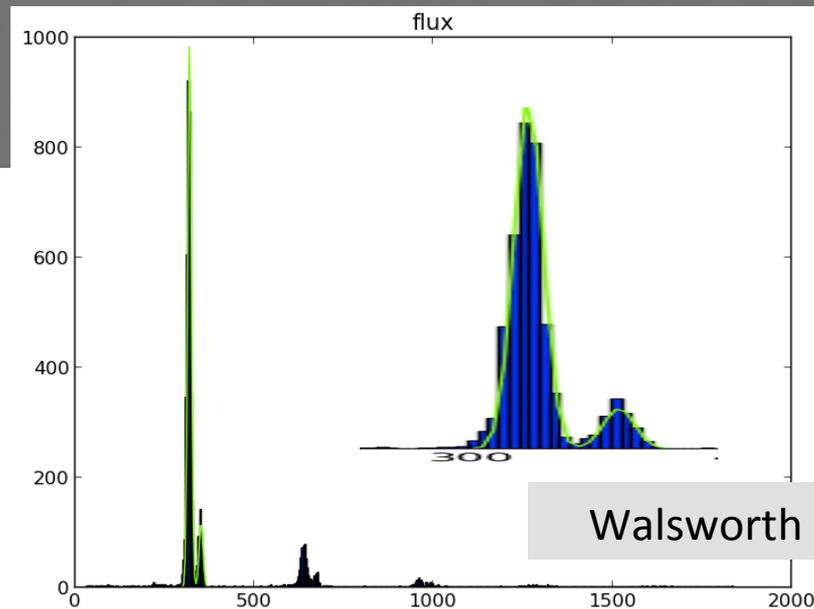
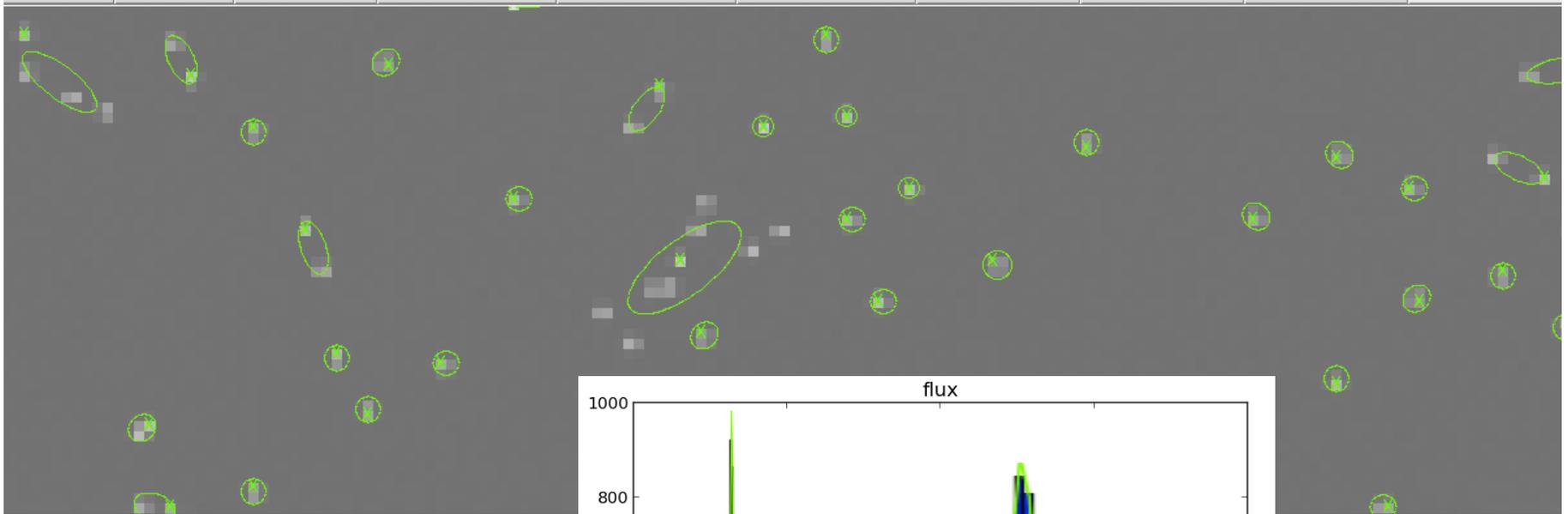
PACCD telecon
8 September 2014

Using X-ray flats for CCD characterization

- Fe55 X-rays produce compact clouds of ~ 1600 electrons, $< 1 \mu\text{m}$
- Standard gain calibration technique for CCDs, used also for diffusion measurements
- Hit shape is symmetric but lateral electric fields in CCD can distort it (edges, tree rings etc)
- Uniform irradiation, not sensitive to the surface \rightarrow can extract astrometry as well and decouple it from photometry
- Easy to have good statistics, in principle it's not too difficult to probe every pixel \rightarrow X-ray flat fielding
- We used large statistics Fe55 datasets collected at BNL
- Initial goal: develop analysis to look at edge and midline effects in CCDs in Fe55 flats

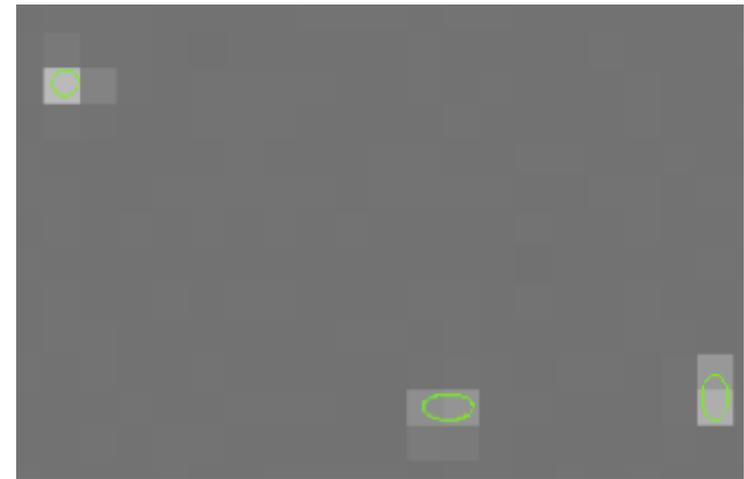
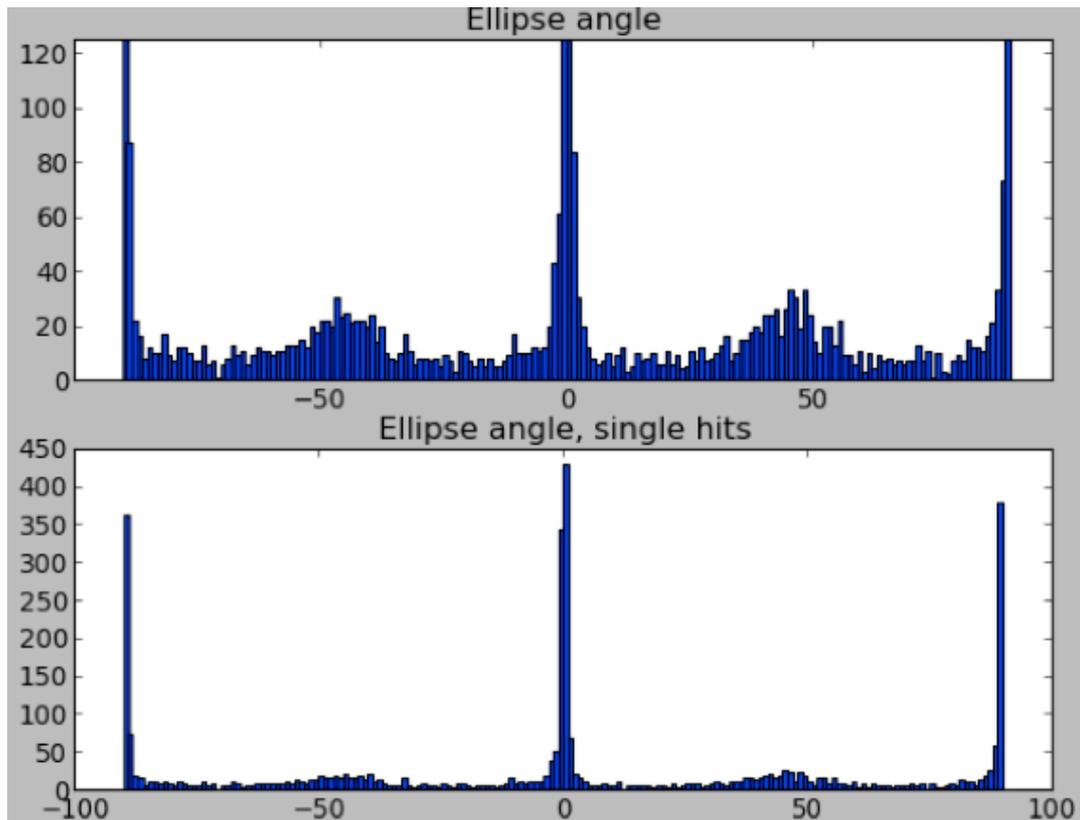
^{55}Fe x-rays

Ellipse fits of DM footprints in ^{55}Fe data (5.9 keV x-rays)



Shape of Fe55 Cluster

- Fe55 hit is expected to be symmetric \rightarrow random orientation of spurious ellipticity \rightarrow flat angle distribution
- Problem: undersampled PSF
 - Pixel : 10x10 micron
 - Diffusion of electron cloud : sigma \sim 3-4 micron
- Ellipse orientation is quantized: -90, 0, +90 deg if use vanilla DM stack



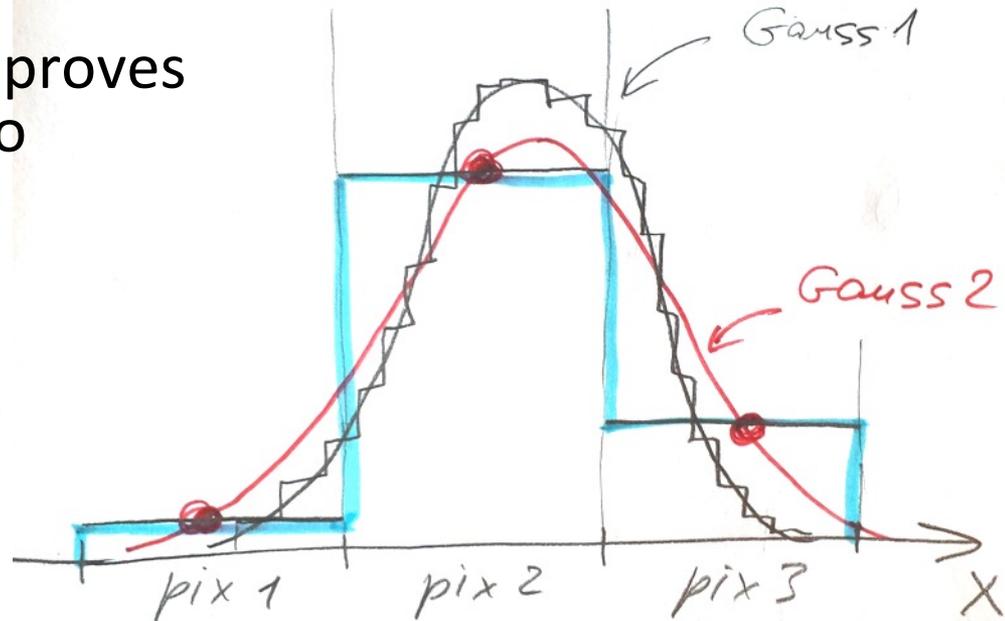
Theta, deg

Undersampling Problem

- Problem: fit function is evaluated in the center of the bin
- This causes biases in fitting of slim x-ray hits (but fitting of fatter stars and galaxies in LSST is presumably ok)
- The correct way to do it is to integrate the function over the bin
- Fine sub-binning of pixels improves the situation without need to integrate properly

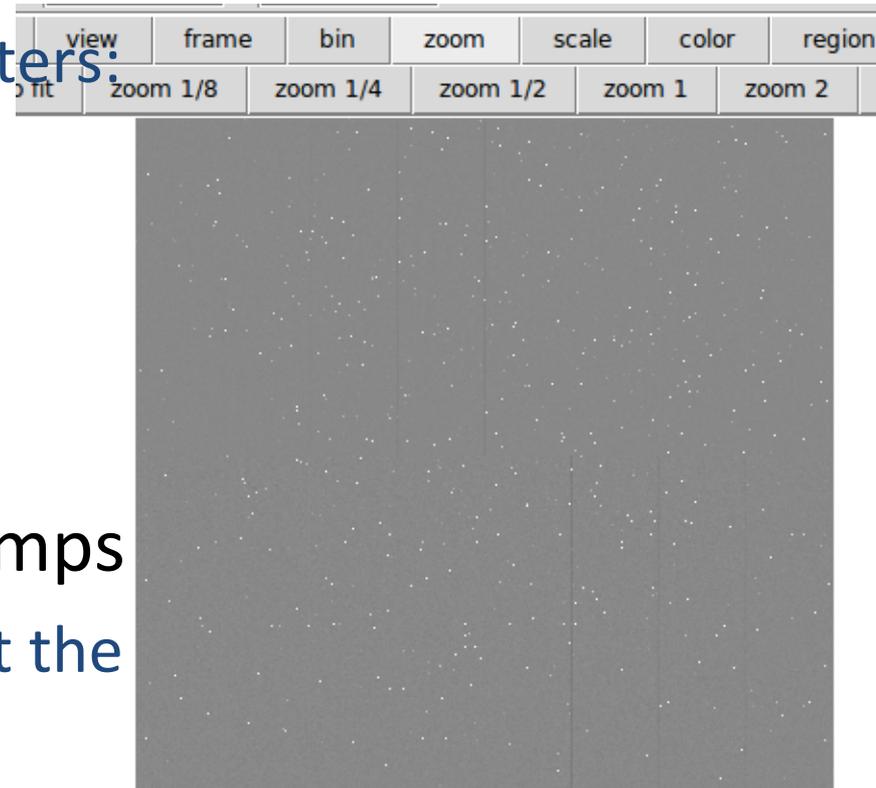
See example:

- Gauss 2 is biased because of undersampling
- Gauss 1 is ok



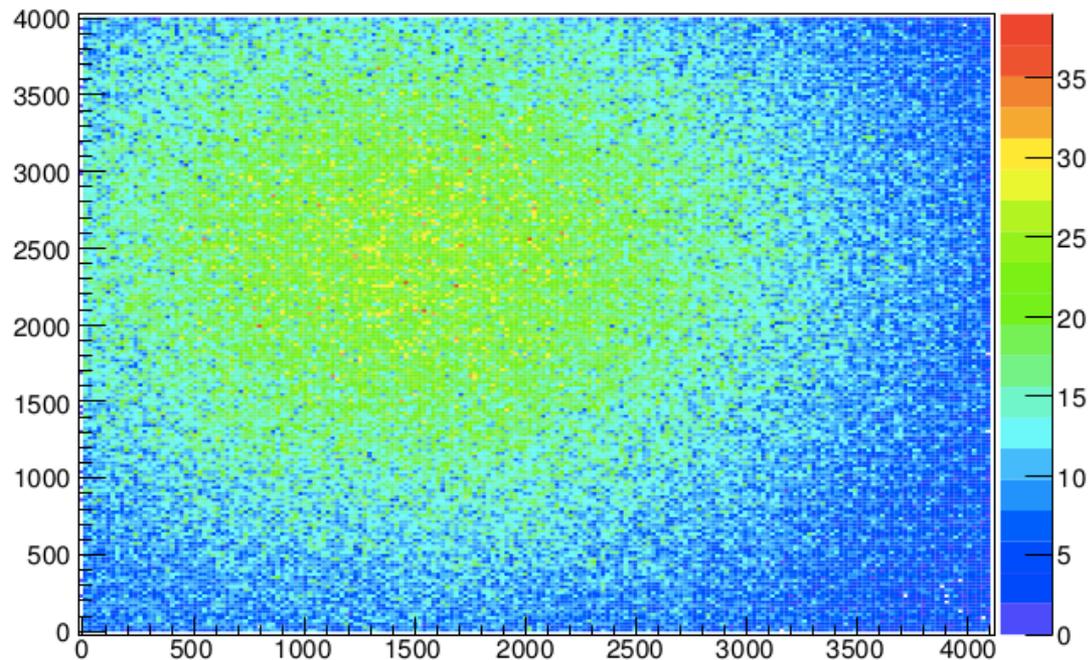
Solving the Undersampling Problem

- Implemented sub-binning
 - Code by E.Sheldon
 - Fit 2-D gaussian with 6 parameters:
 $x, y, g1, g2, \text{sigma}$ and flux
 - 16x16 sub-bins in one pixel
 - Allows priors for parameters
- Also needed to correctly assemble the mosaic for 16 amps
 - Important since want to look at the edges and midline
 - code by M.Fisher-Levine, P.Price



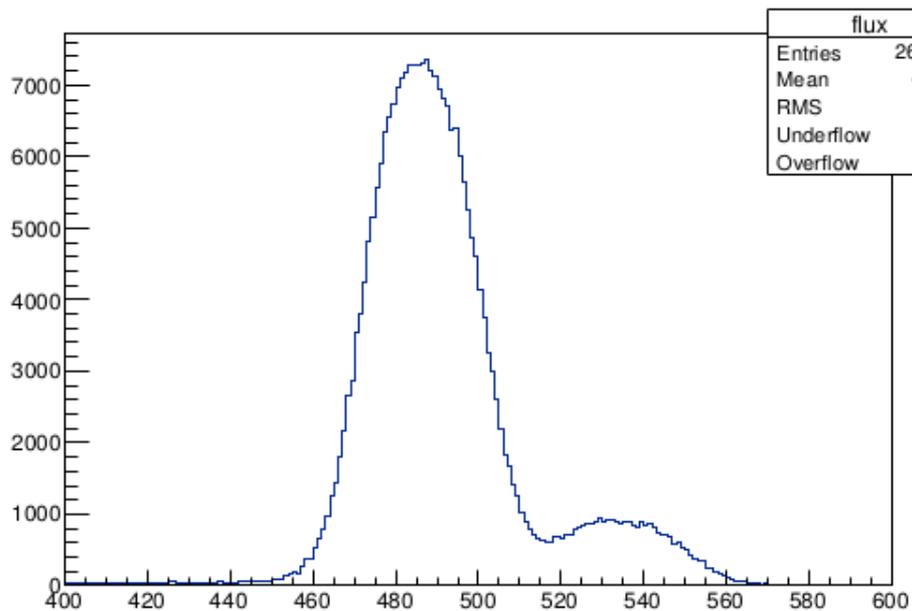
X-ray Hit Map

- LSST DM stack does x-ray finding and background subtraction
- Require two adjacent pixels above 5 sigma threshold, “grow” = 2
- 2.4 M reconstructed footprints for 16M pixels
- 1.6 M used for analysis (removed fit failures and blended hits, select good fit errors)
 - This statistics could be easily increased

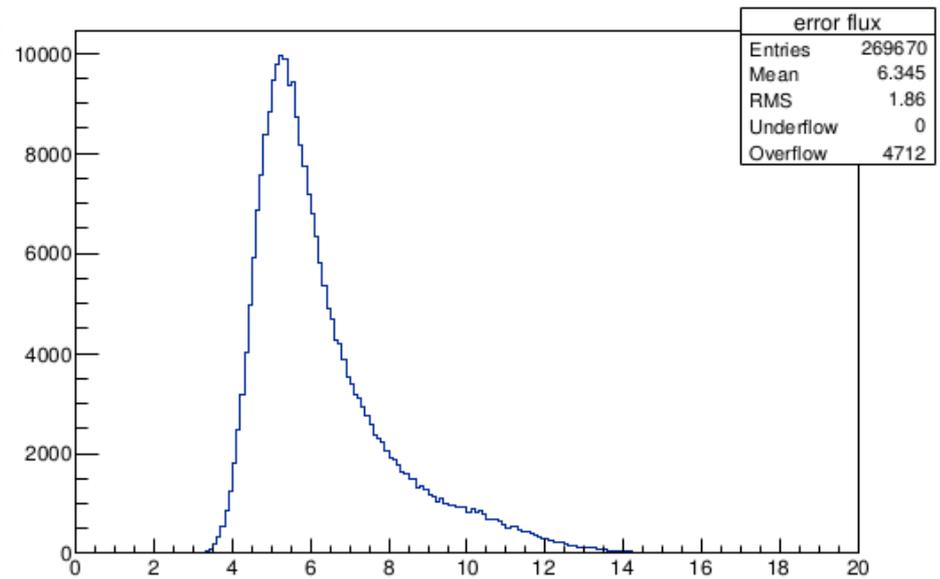


Flux

- All 16 amplifiers overlaid
- No gain corrections



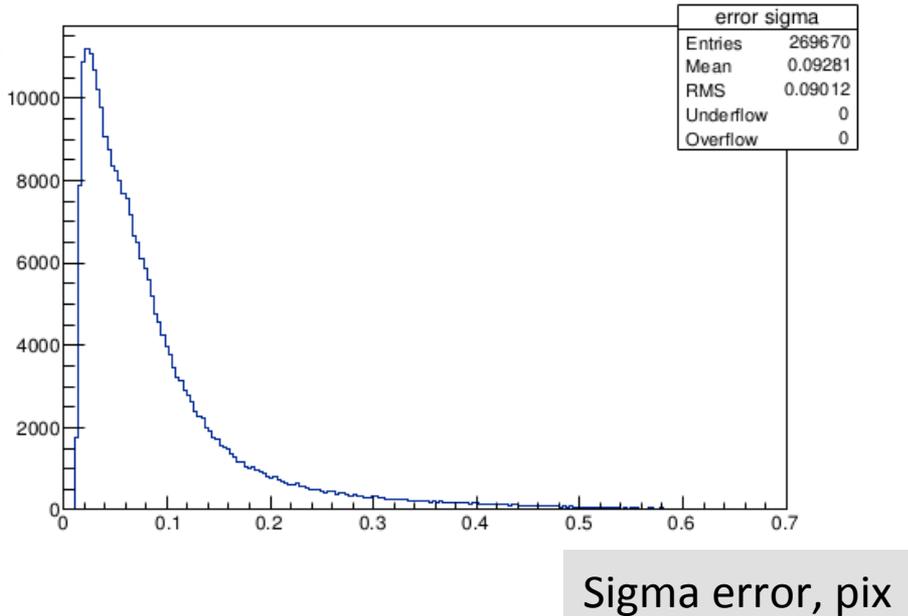
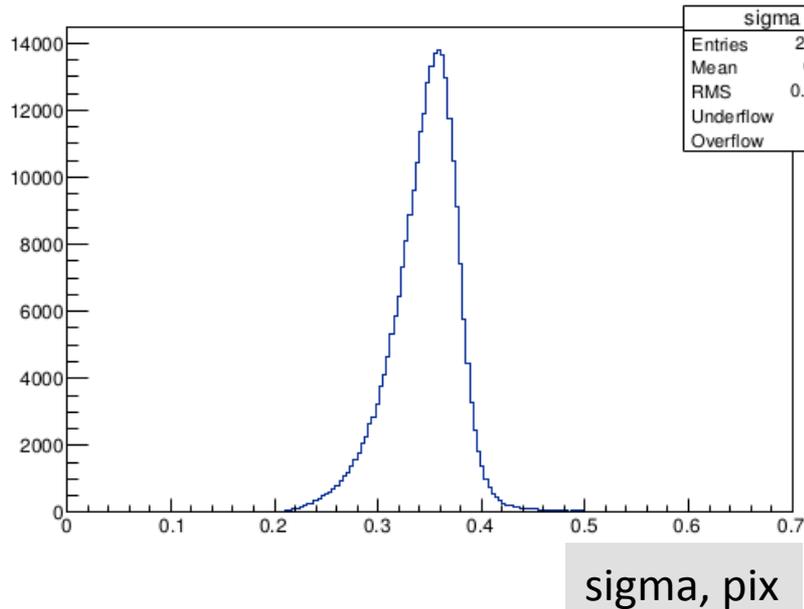
Flux, ADU



Flux error, ADU

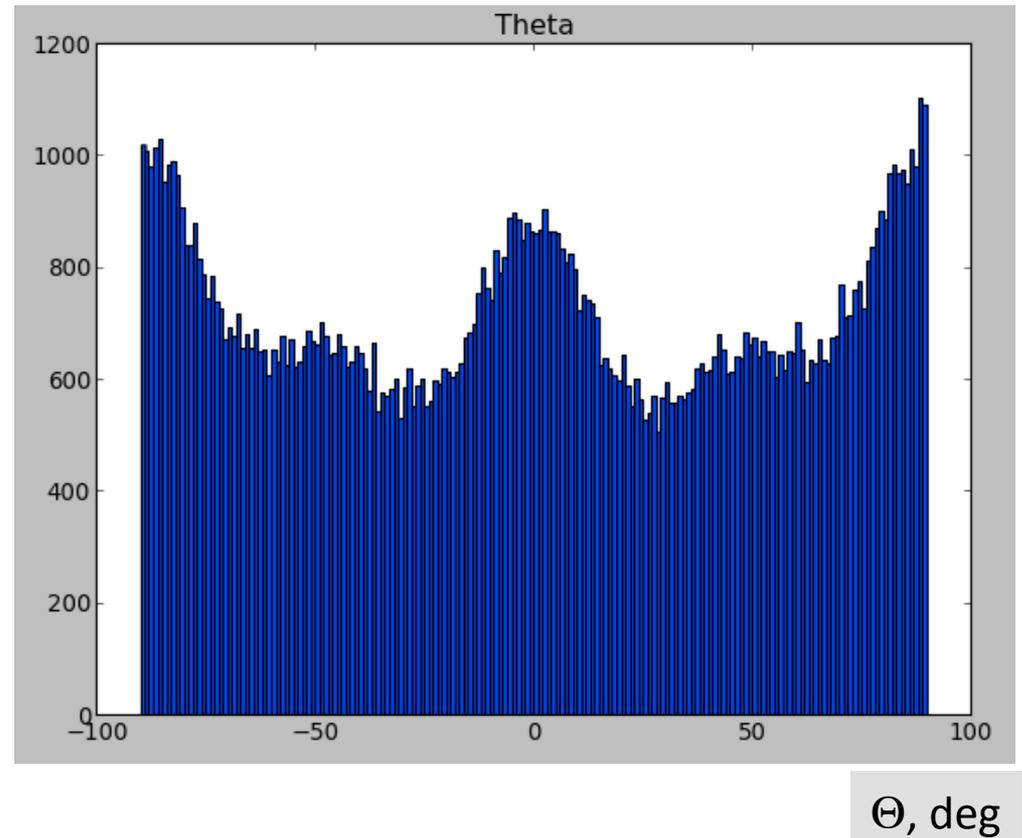
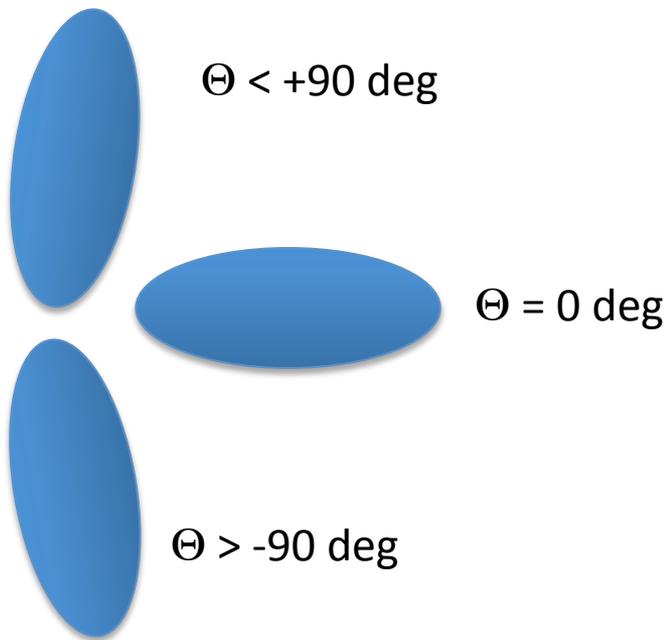
PSF Size

- Distribution is skewed due to varying conversion depth
 - Average conversion depth ~ 30 micron
- This has been used before for Si diffusion measurement (Kotov et al)

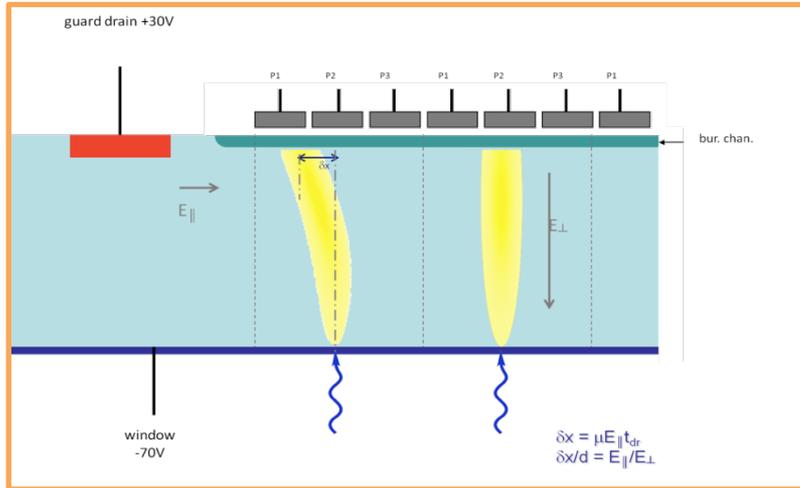


Ellipse Orientation

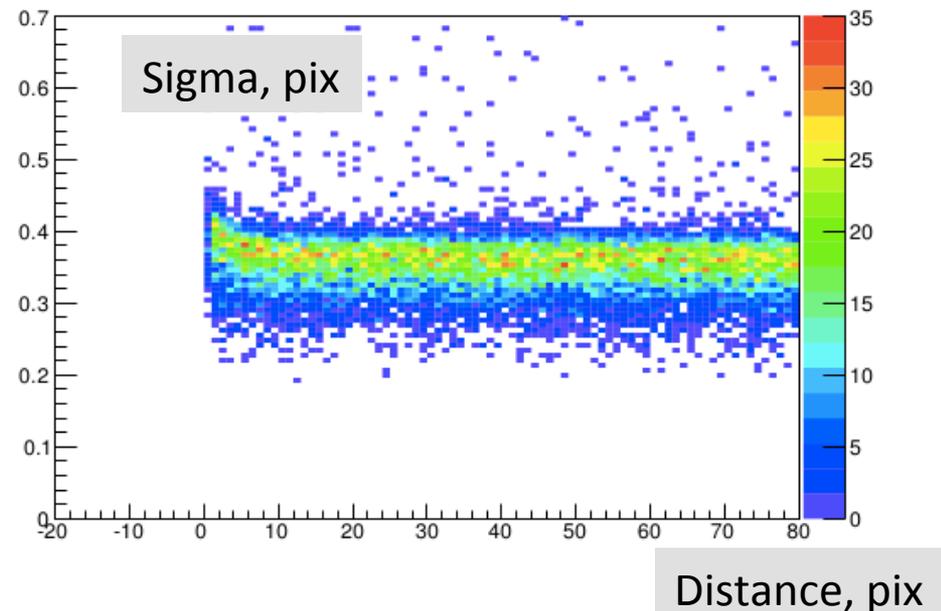
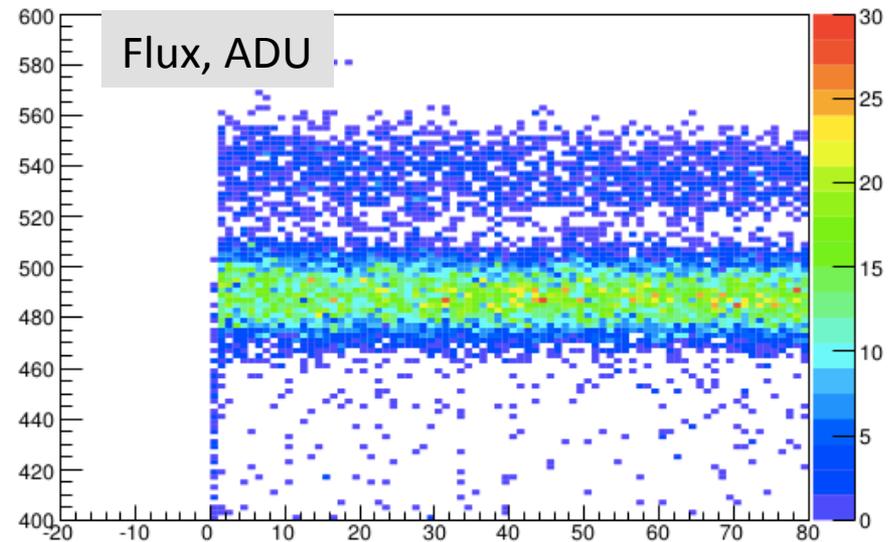
- Select single hits and reasonable fit errors



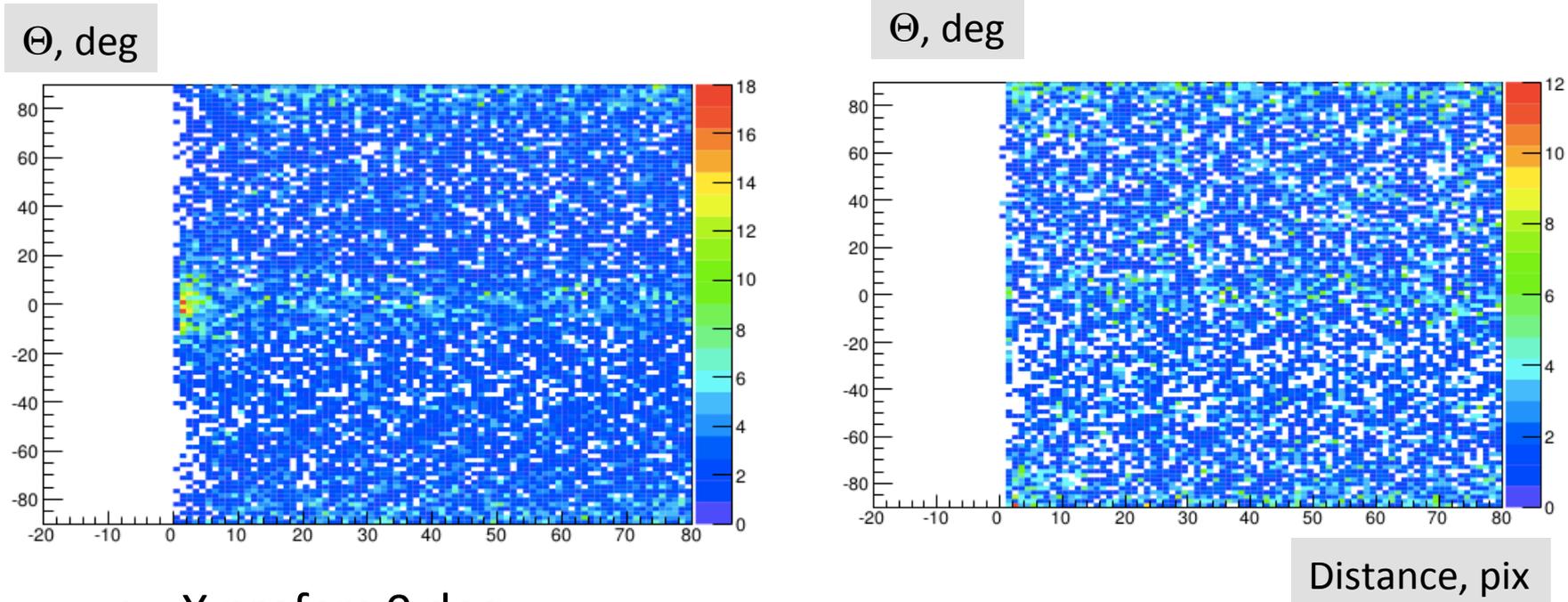
Flux and PSF Size on the Edge



- Flux is constant
- Sigma is increasing near the edge



Ellipse orientation on the edge



- X prefers 0 deg
- Y prefers ± 90 deg
- Not very good observable since orientation is not defined for symmetric hit

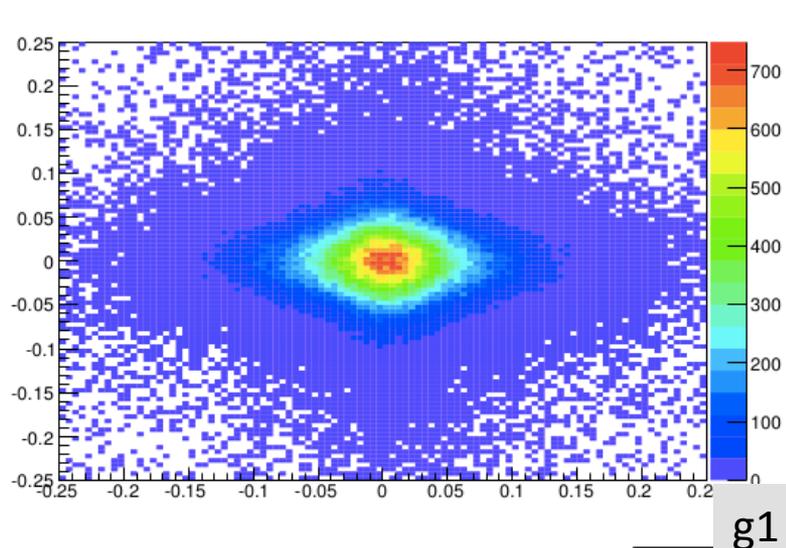
Shear (Ellipticity) of Hits

Weak lensing definitions for g1, g2 shear

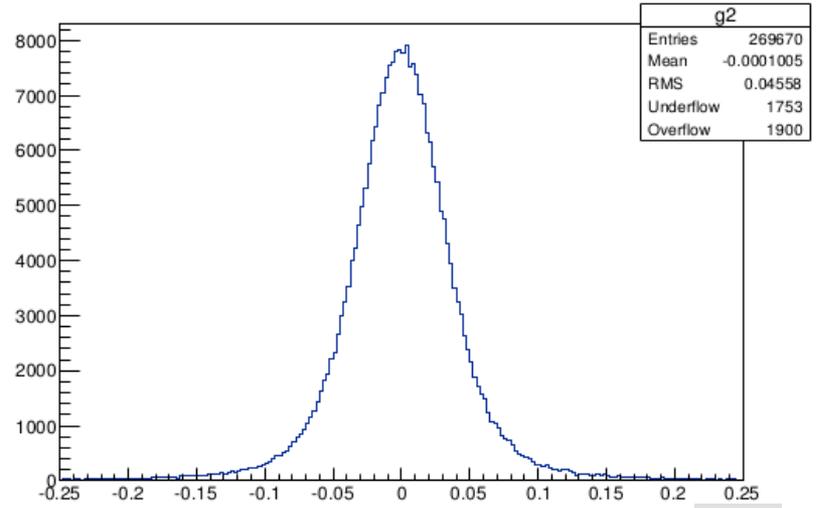
$$g = (a-b)/(a+b)$$

$$\tan(2\theta) = g2/g1$$

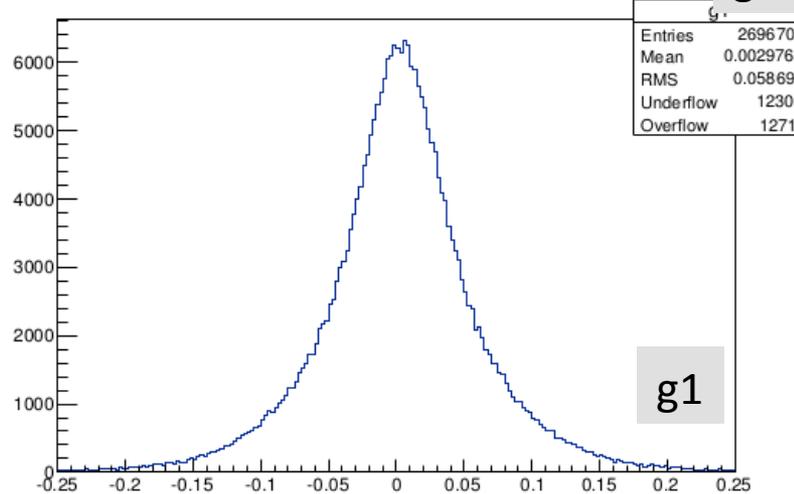
g2



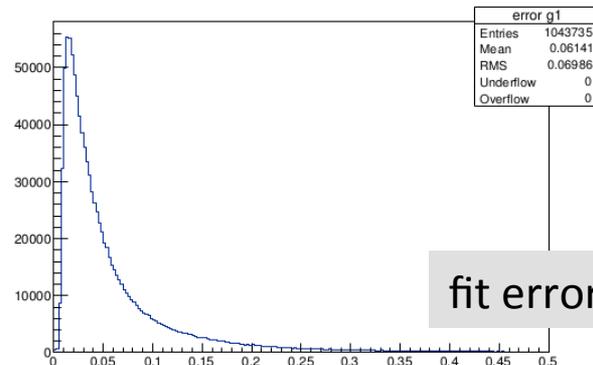
g1



g2

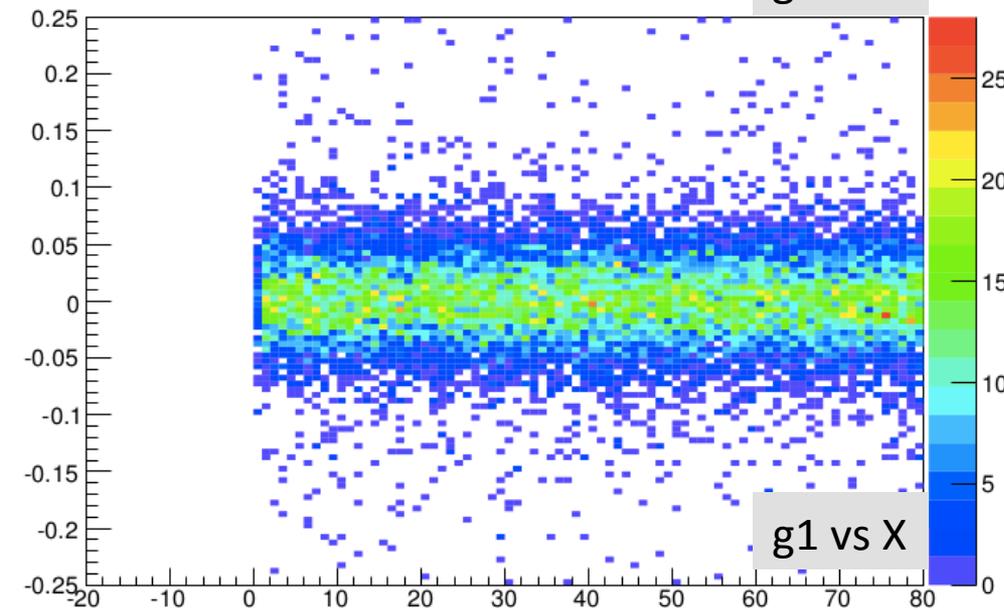
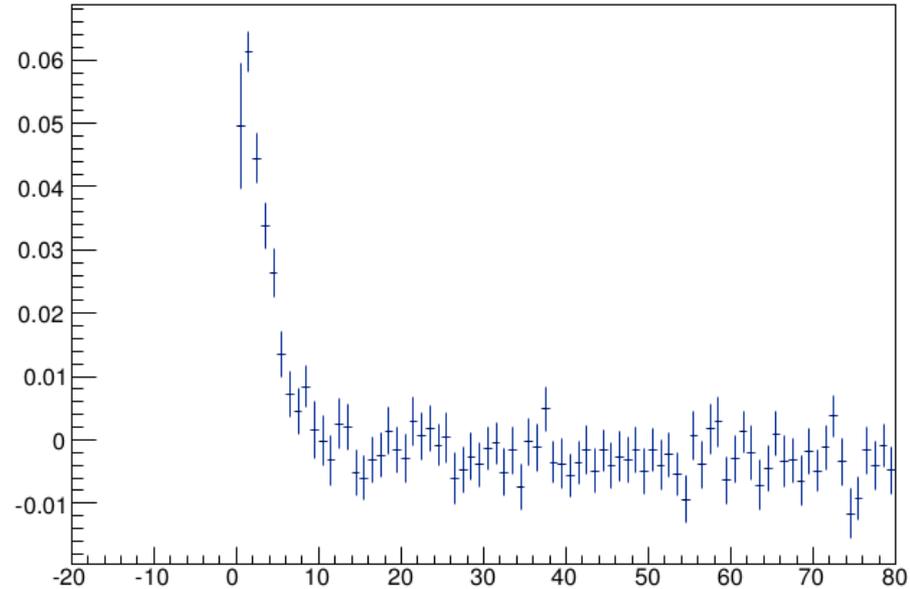
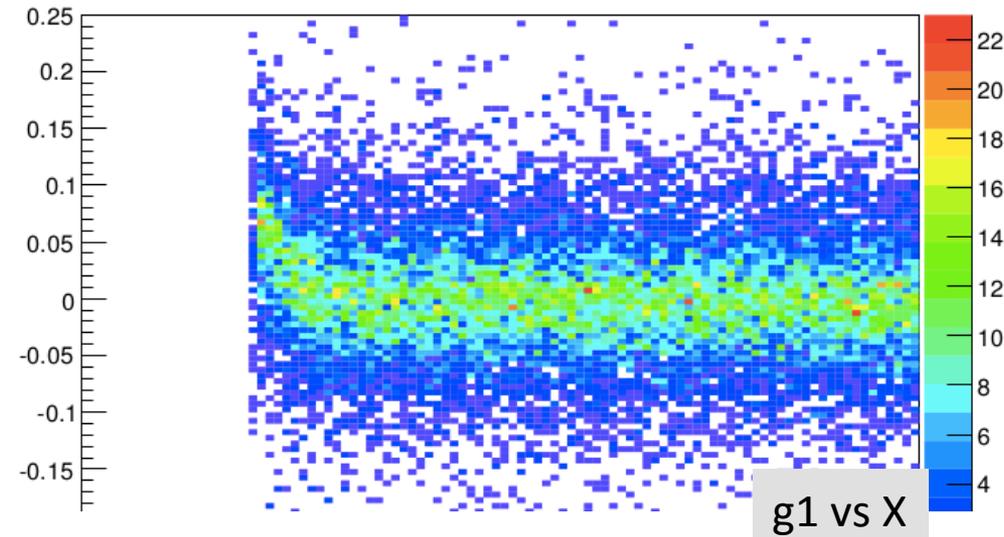


g1



fit error g1

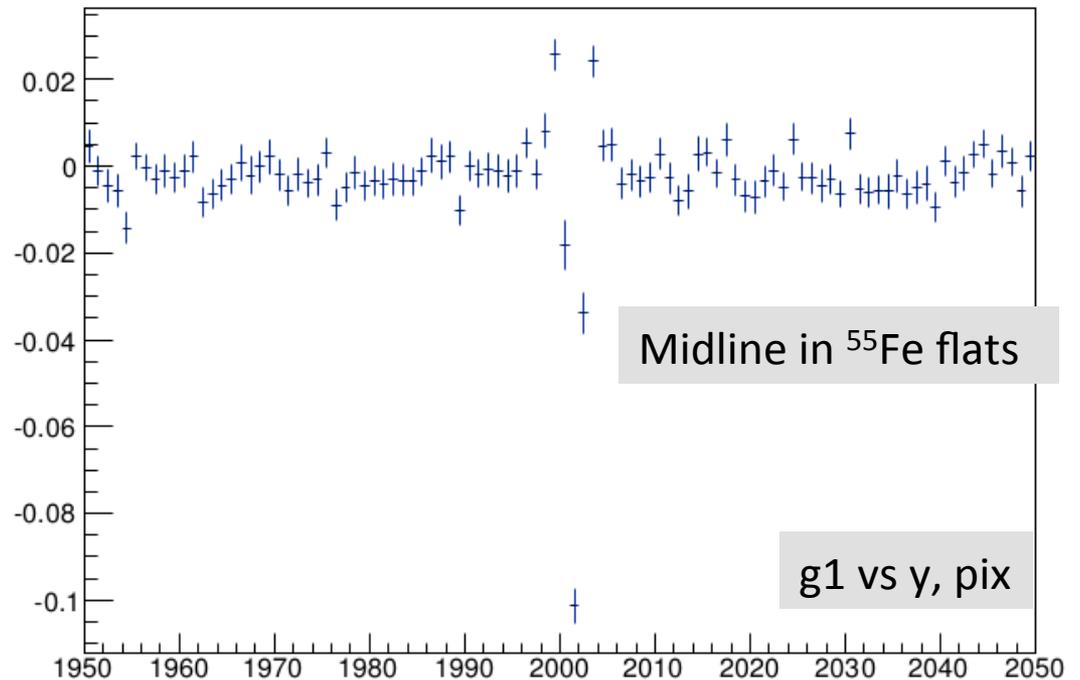
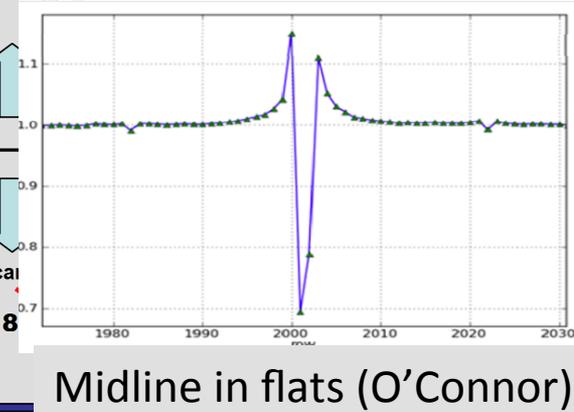
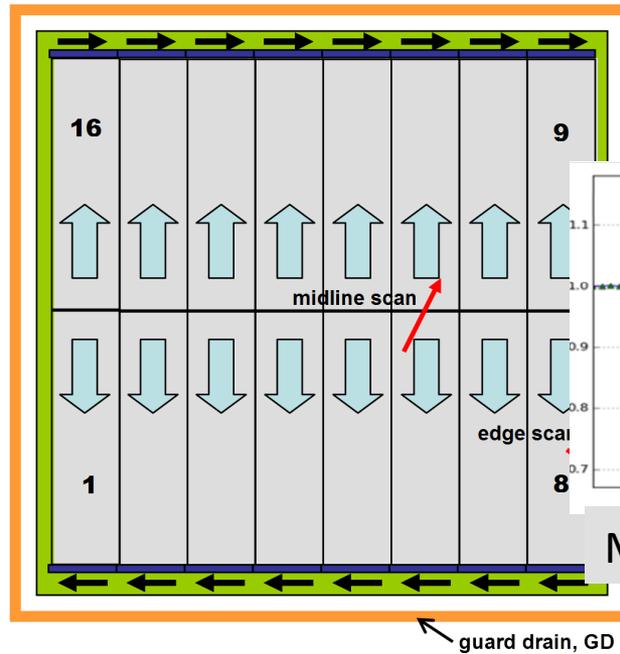
Edge Effect seen in Fe55 flats!



- $g1$ positive \rightarrow elongation along x , affects ~ 10 pixels
- $g2$ does not change \rightarrow no 45° component

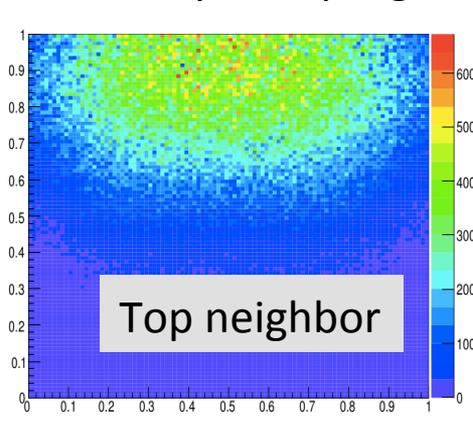
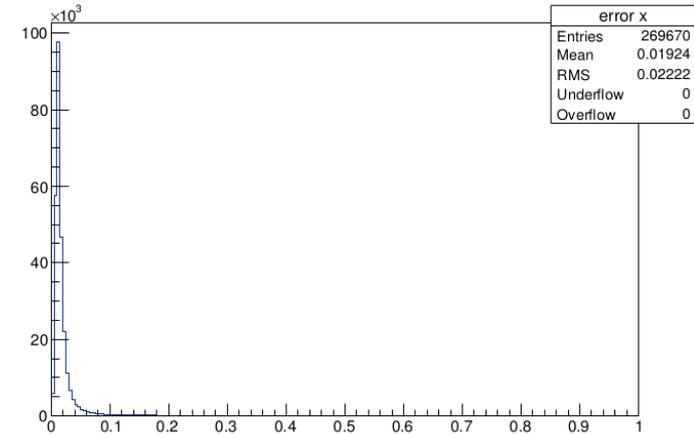
Midline

- Anti-bloom stop implant between top and bottom halves
- Causes rotation of ellipticity when crossed around pixel #2002



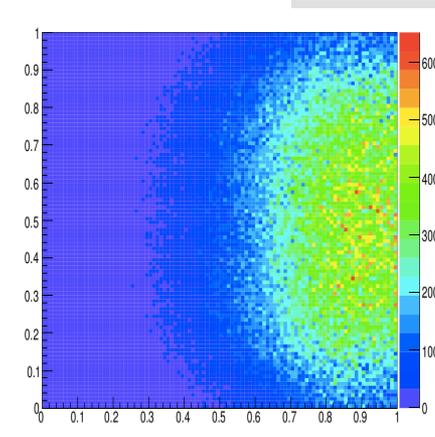
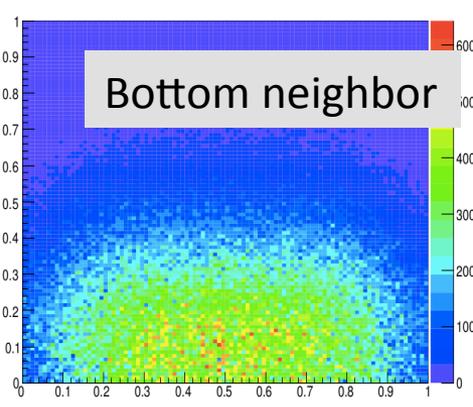
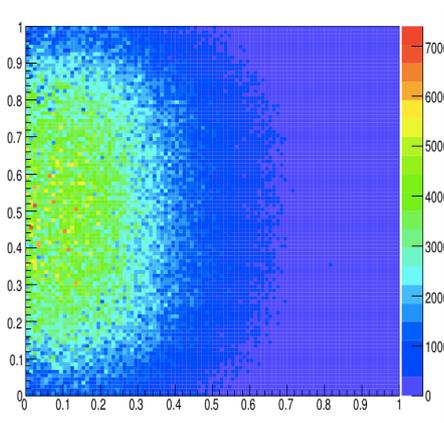
Correlations with neighbors

- Charge in the top, bottom, left, right neighbors as function of centroid (x,y)
 - Centroid is well reconstructed, small errors
- Appear symmetric, quantitative analysis in progress



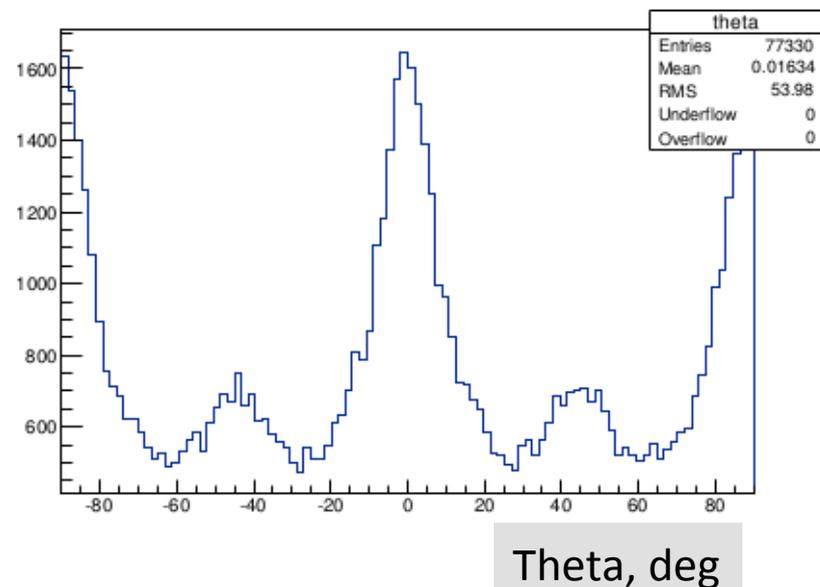
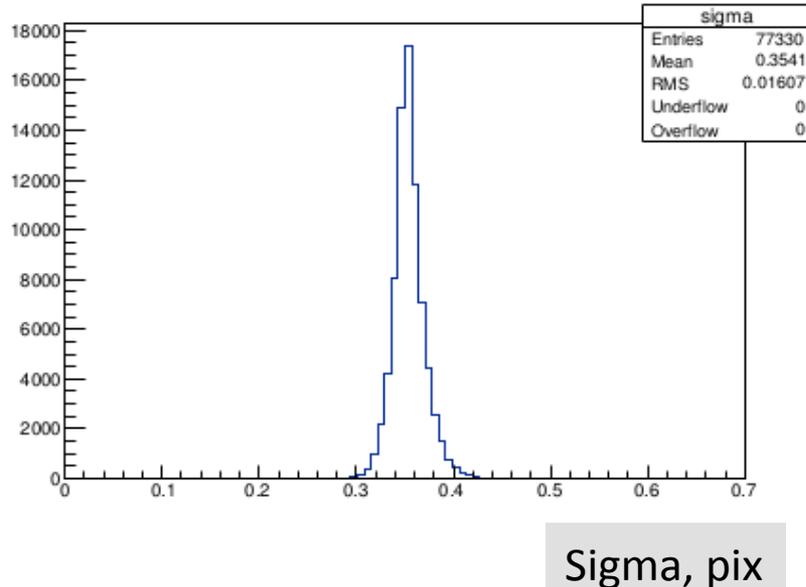
4.1	37.1	-1.9
34.1	354.1	24.1
4.1	25.1	0.1

Centroid error, pix



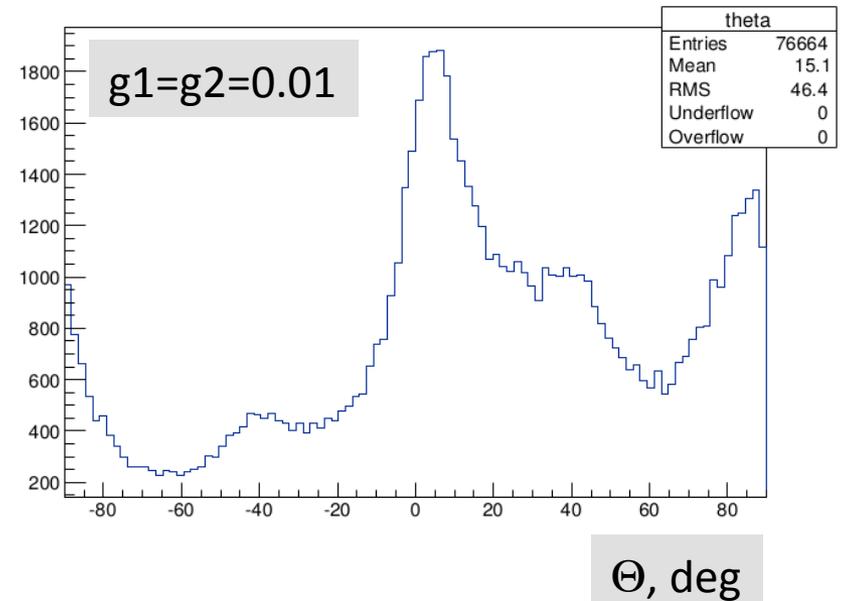
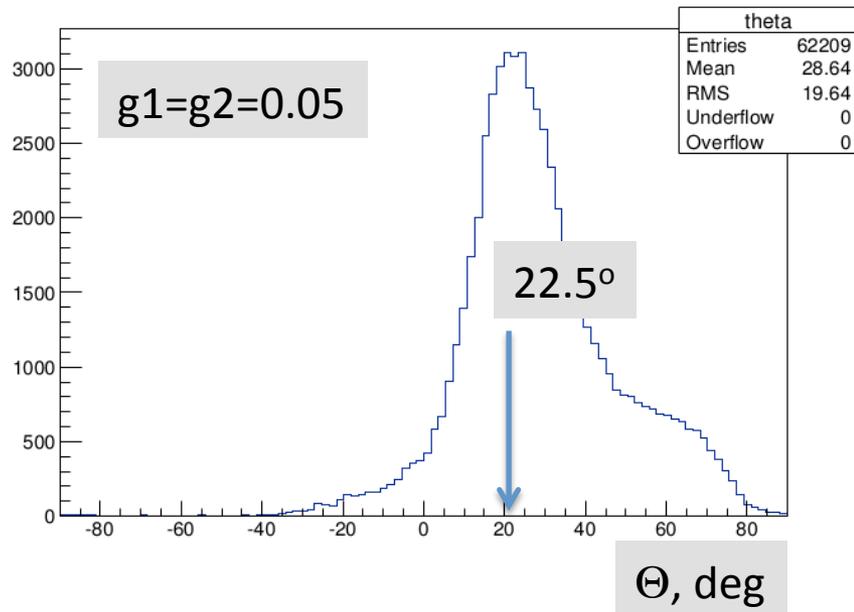
Toy MC: symmetric hits

- Goals:
 - Check assumptions
 - Estimate accuracy
- Simulated Fe55 hits as 2D Gaussians with 6 parameters, passed it through the same analysis
 - Shown below $g1 = g2 = 0$, $\sigma = 3.5 \text{ um}$, $\text{flux} = 480 \pm 10$
- Looks very similar to the real data



Toy MC: sheared hits

- Sensitivity to shear : $g1 = g2 \rightarrow \Theta = 22.5 \text{ deg}$
 - $g1 = g2 = 0.05 \rightarrow \text{ok}$
 - $g1 = g2 = 0.01 \rightarrow \text{marginal}$
- \sim Agrees with $g1, g2$ errors from the fit; need quantitative analysis



Summary

- Fe55 flat fielding is a viable tool to characterize astrometric distortions in CCDs
 - Does not depend on QE → a way to disentangle photometric and astrometric effects
- Acknowledgements:
 - Merlin Fisher-Levine, Paul Price: DM code
 - Erin Sheldon: ngmix fitter
 - Paul O'Connor, Ivan Kotov: Fe55 datasets